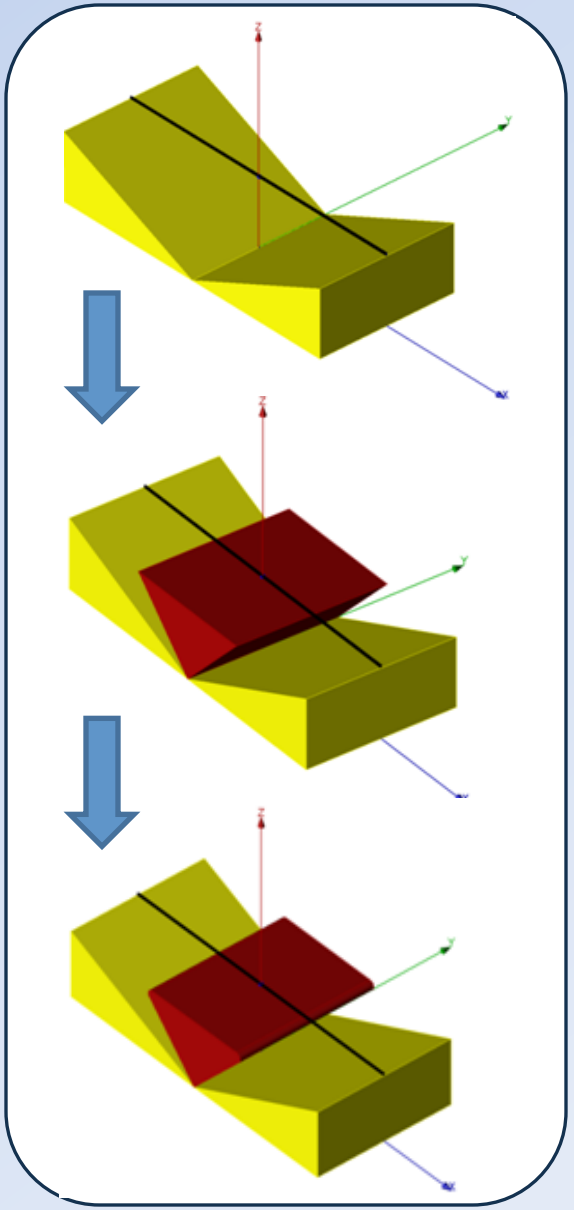
Design of Antennas with an Iso-flux Pattern to Achieve Suppression of Radiation along Zenith

Mohamed Abdel-Mageed, Sidharath Jain, Kadappan Panayappan, and Raj Mittra

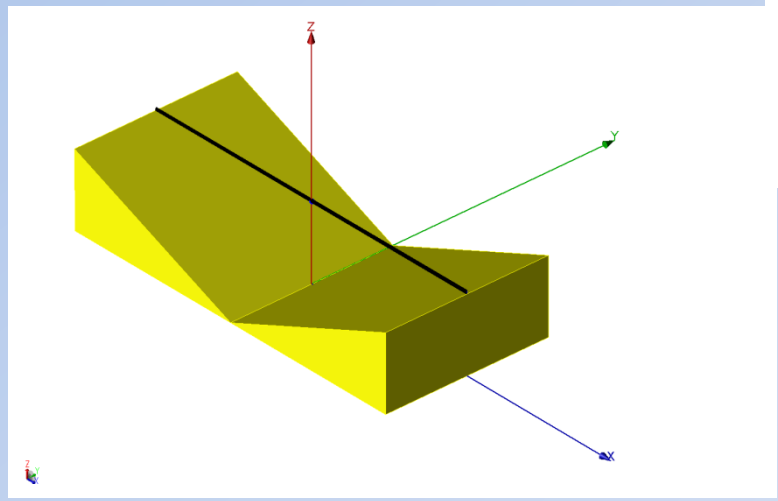
EMC Lab, Department of Electrical Engineering, The Pennsylvania State University 319 EE Building, University Park, PA 16802, USA

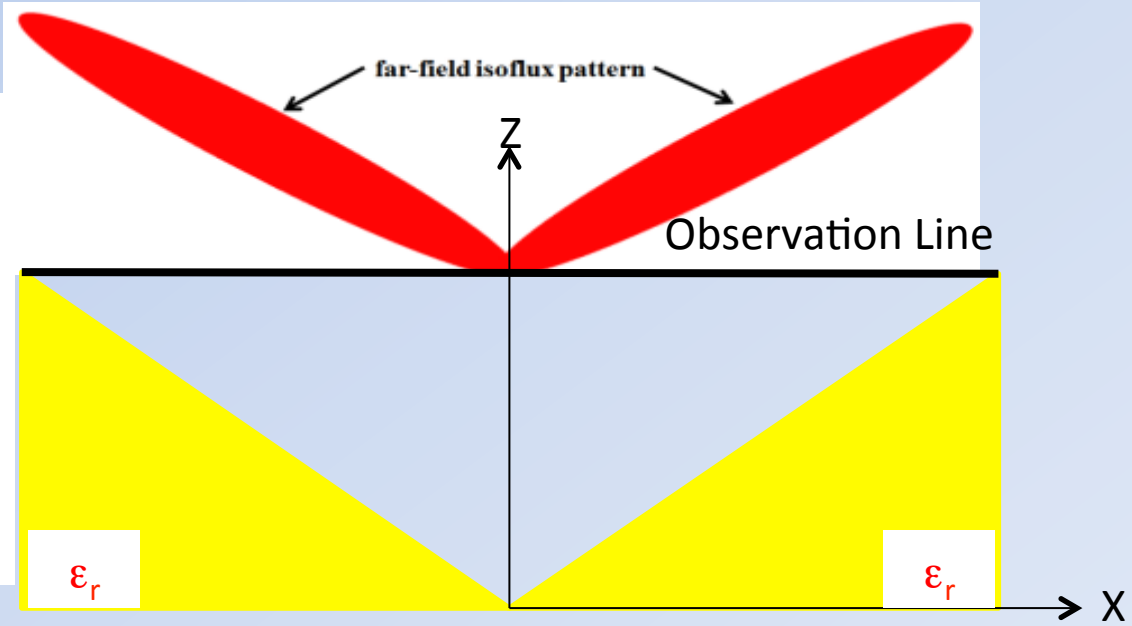
Outline

- Motivation
- Previous Leaky-wave Antenna Structure
- Field Transformation (FT) Approach
- The Iso-flux Pattern Antenna (IPA)
- The Sharp-Edged IPA
- The Round-Edged IPA
- Far-field Radiation Pattern Results Comparison
- Conclusion



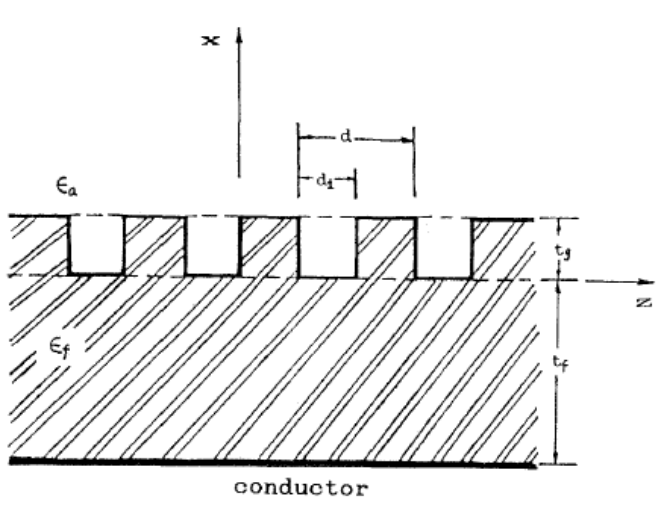
Motivation



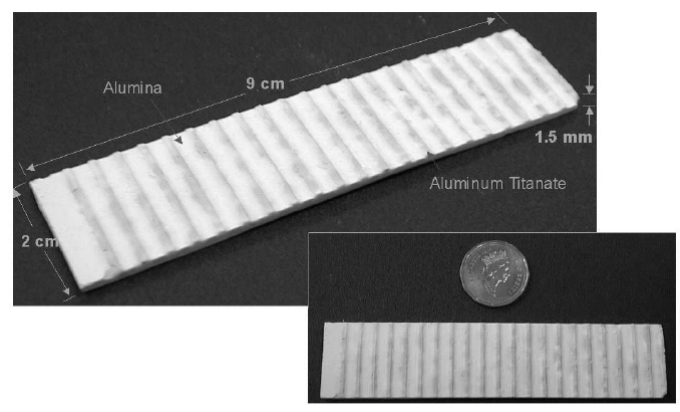


- Generation of an iso-flux radiation pattern in the millimeter band, with
  - adequate suppression of the radiation along the zenith
  - iso-flux type of pattern
  - low Side Lobe Level (SLL)

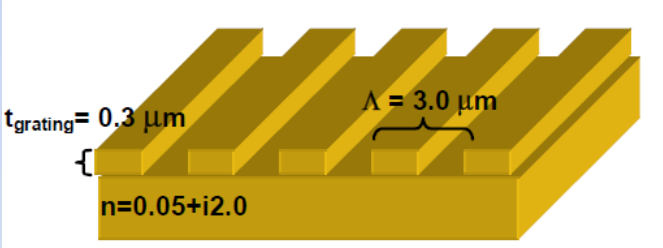
Previous Work



[1] Homogeneous dielectric leaky wave antenna



[2] Heterogeneous dielectric leaky wave antenna



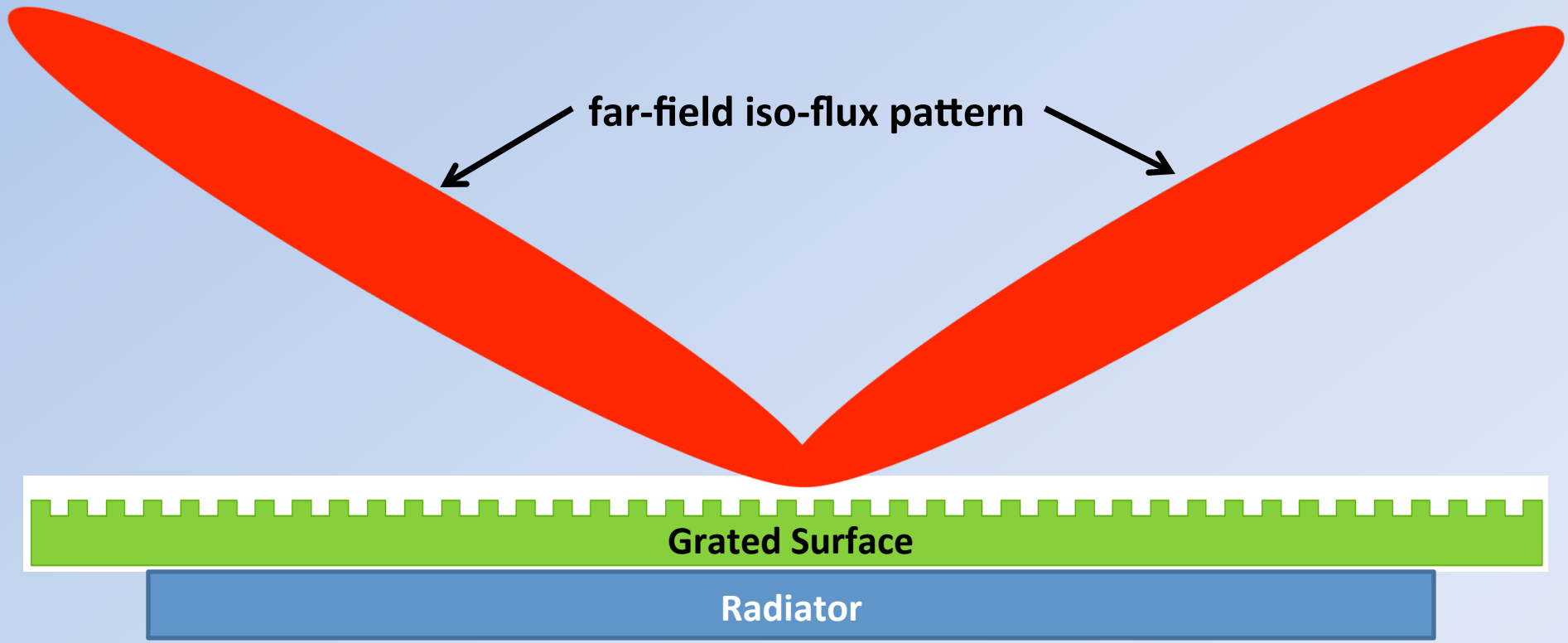
[3] Periodic nickel structure

[1] X. Shanjia and W. Xinzhang, "Improved Perturbation Analysis of Dielectric Grating Antenna," *International Journal on Infrared and Millimeter Waves*, Vol. 10, No. 2, 213-230, 1989

[2] Y. M. M. Antar, H. F. Hammand, A. P. Freundorfer and M. Sayer, "A New Dielectric Grating Antenna at Millimeter Wave Frequency," *IEEE Trans. Antennas Propagat.*, Vol. 52, No. 1, pp. 36-44, Jan. 2004

[3] S. A. Kemme, A. A. Cruz-Cabrera, D.W. Peters, A. R. Ellis, T.R. Carter and S. Samora, "Tailored Surfaces for Managing Thermal Emission: Plasmon/Photon Coupling Using Diffractive Optics Technology," *Proc. of SPIE*, Vol. 6883, 68830W, 2008

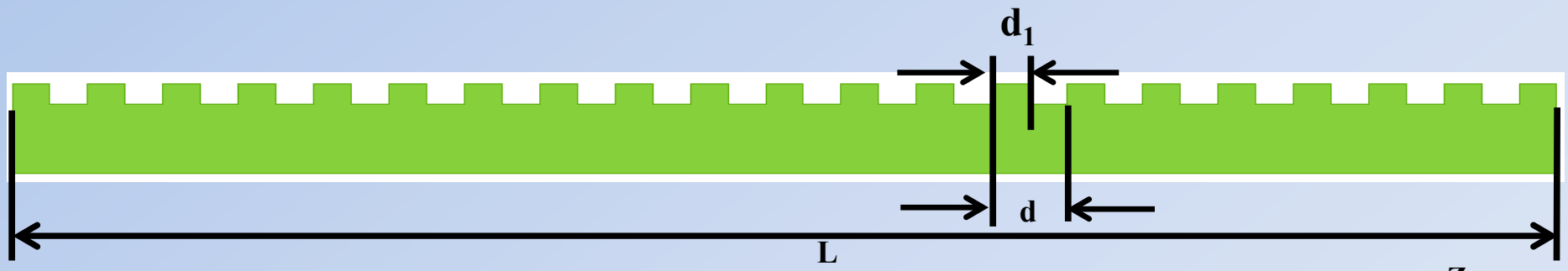
Previous Work (Leaky Wave Antenna)

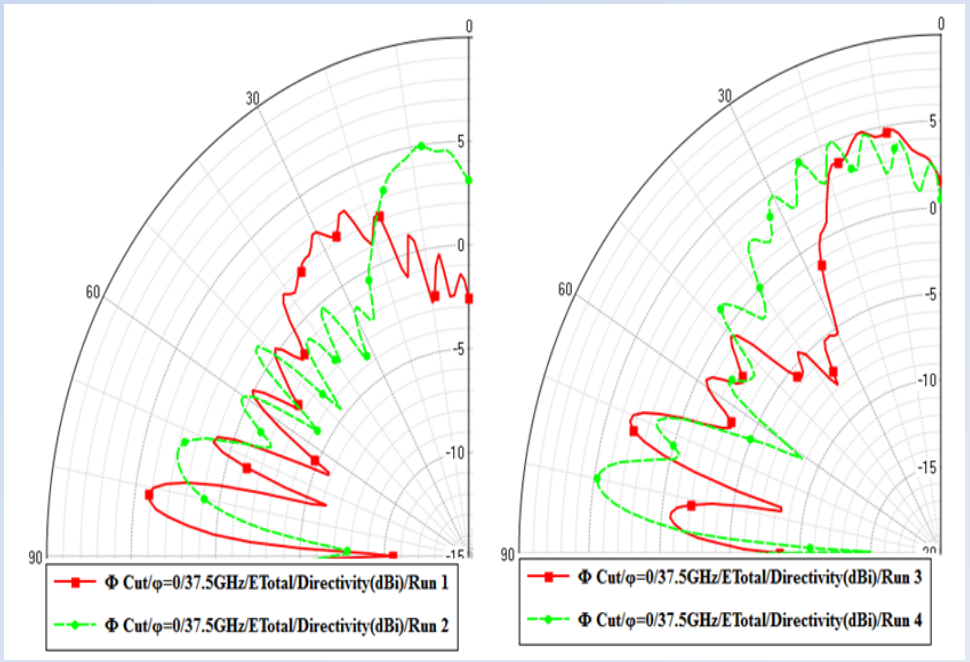


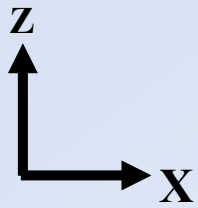
A leaky wave antenna had been used to generate an isoflux radiation pattern in the millimeter band, with main lobes located as far from broadside as possible, when the underside of the surface is excited

Results for Leaky Wave Antenna (Previous)

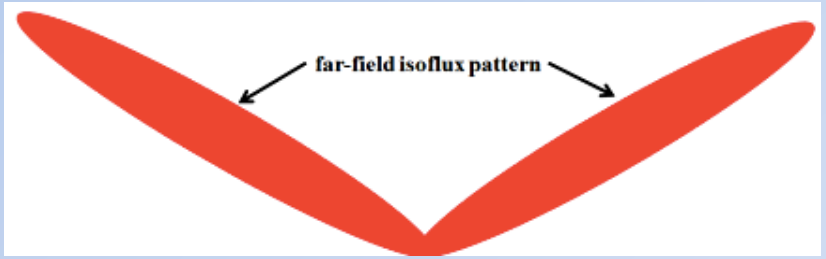
λ_0(mm)	L(λ_0)	d(λ_0)	w(λ_0)	d_1(λ_0)	AR	t_g(λ_0)	t_s(λ_0)	ε_m
8.00	2→20	0.5	2.5	0.25	0.5	0.15	0.5	2.1

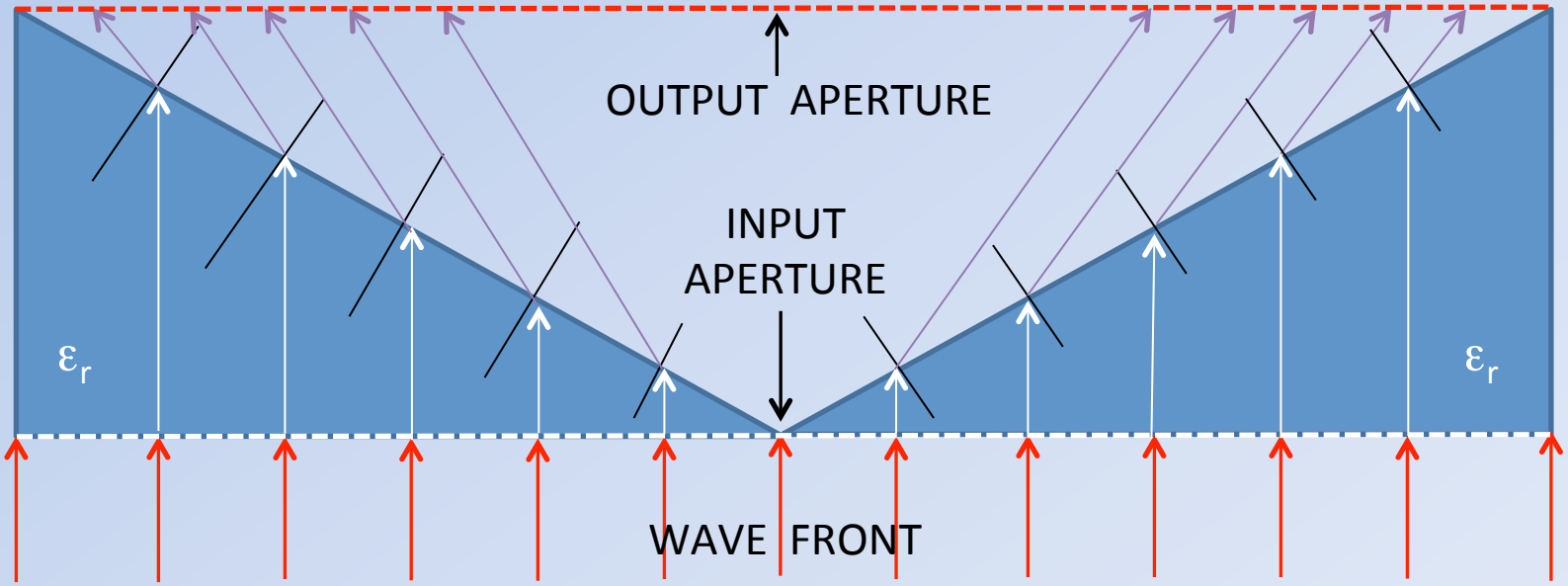






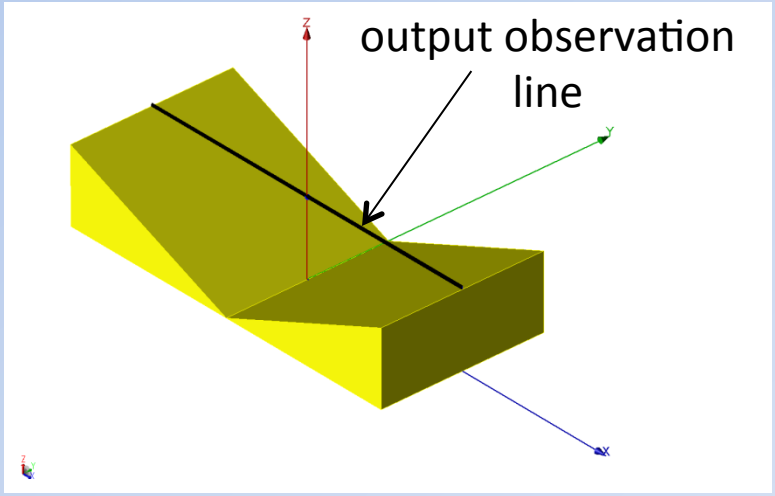
Field Transformation (FT) Approach





Two right-angled triangular prisms are used to divert the wave that is impinging upon the base of the prism at an angle away from the zenith

Huygens's Principle



In order to calculate the far-field pattern, we use equivalent electric and magnetic currents over the output aperture derived from the tangential components of the induced fields

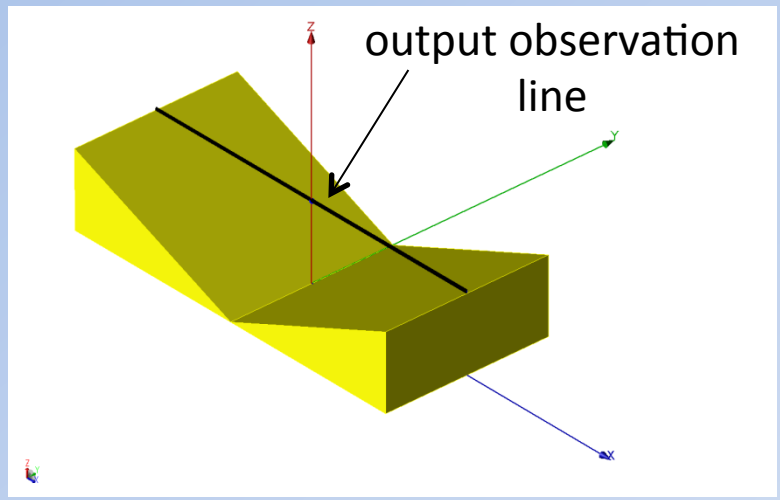
$$N_\theta = \iint_s [Jx\cos\theta\cos\phi + Jy\cos\theta\sin\phi - Jz\sin\theta]\, e^{+jkr'\cos\psi}\, ds'$$

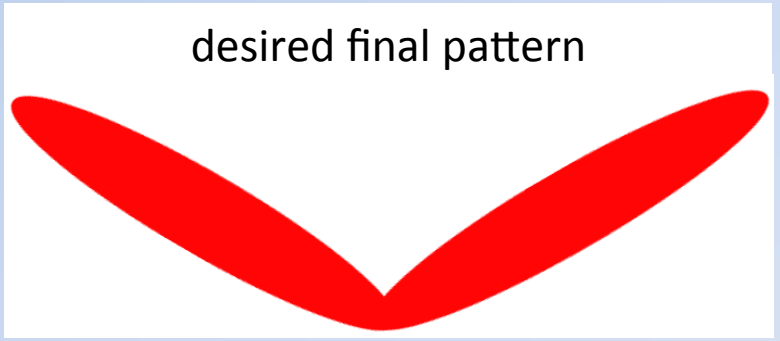
$$N_\phi = \iint_S [-Jx\sin\phi + Jy\cos\phi]\, e^{-jkr'\cos\psi}\, ds'$$

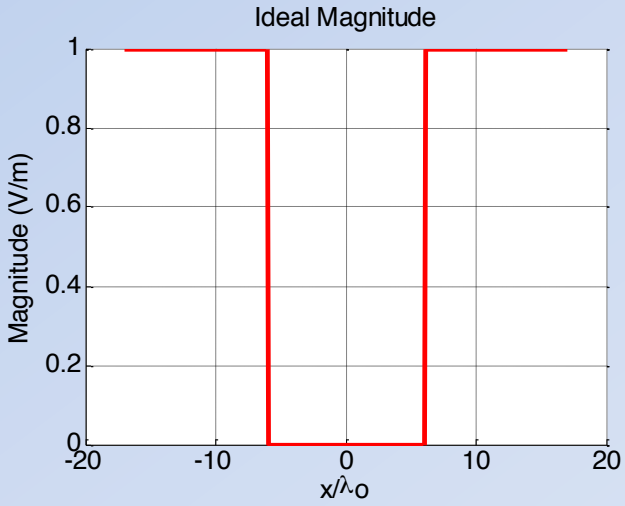
$$L_\theta = \iint_s [Mx\cos\theta\cos\phi + My\cos\theta\sin\phi - Mz\sin\theta]\, e^{+jkr'\cos\psi}\, ds'$$

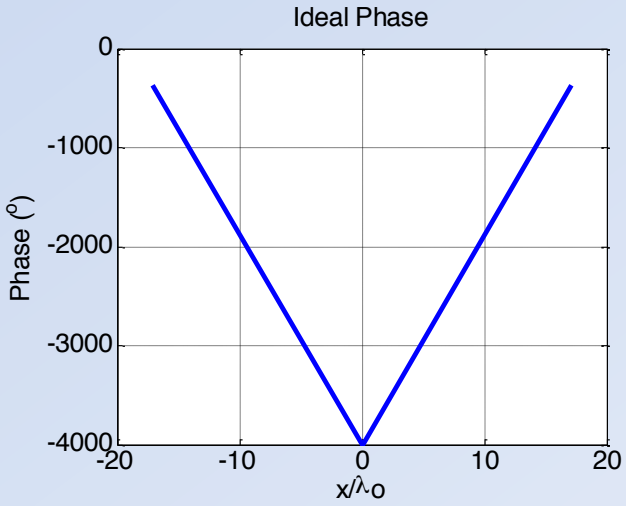
$$L_\phi = \iint_S [-Mx\sin\phi + My\cos\phi]\, e^{+jkr'\cos\psi}\, ds'$$

Ideal Case



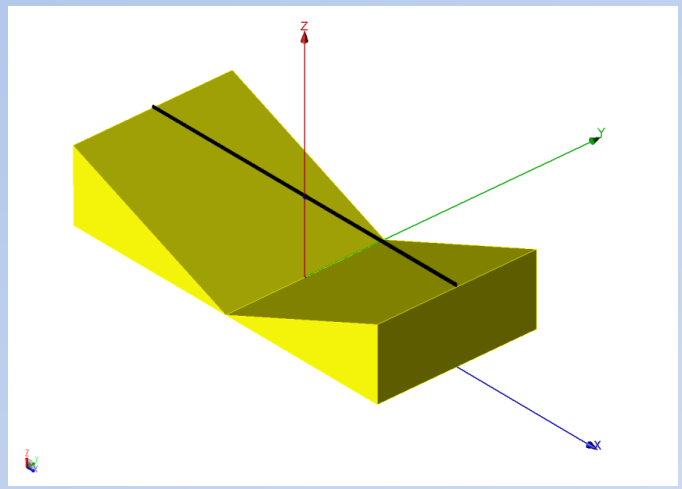


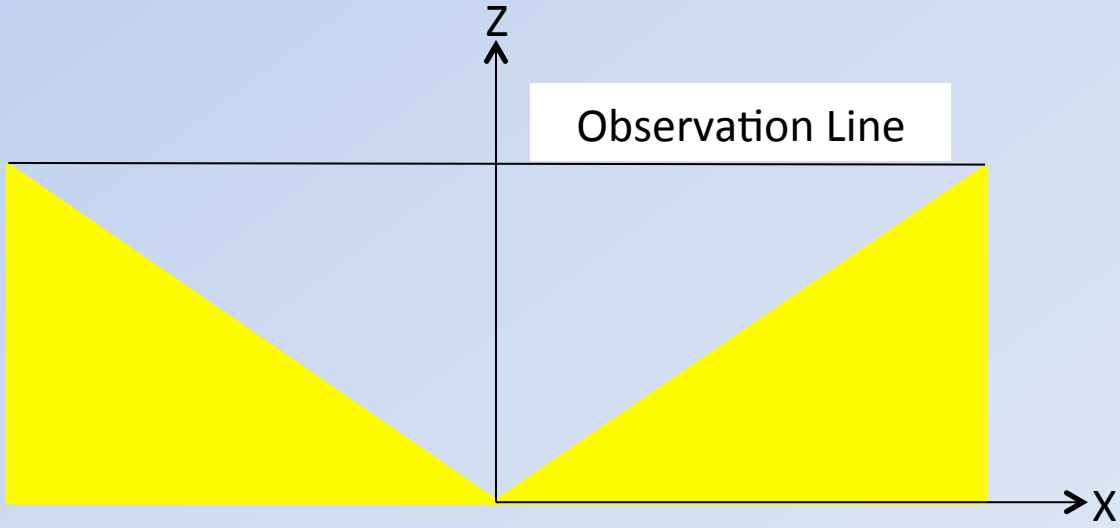




In order to obtain the Isoflux radiation pattern above, we would ideally need a design that generates the above magnitude and phase distributions at the output observation line

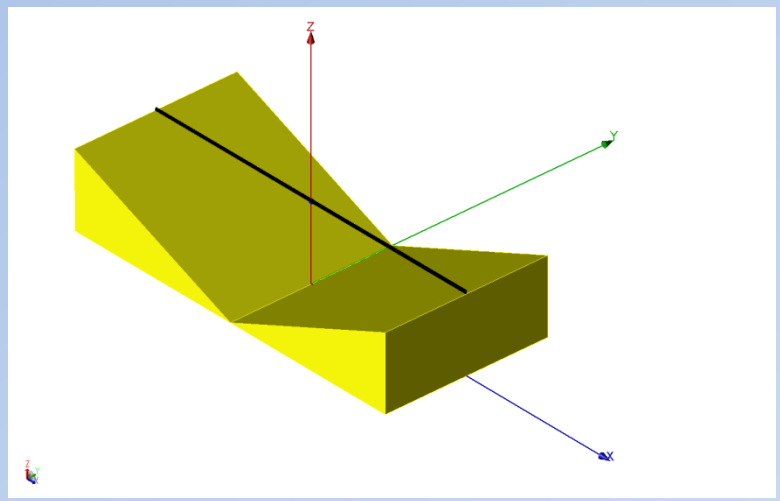
The Isoflux Pattern Antenna (IPA) Structure



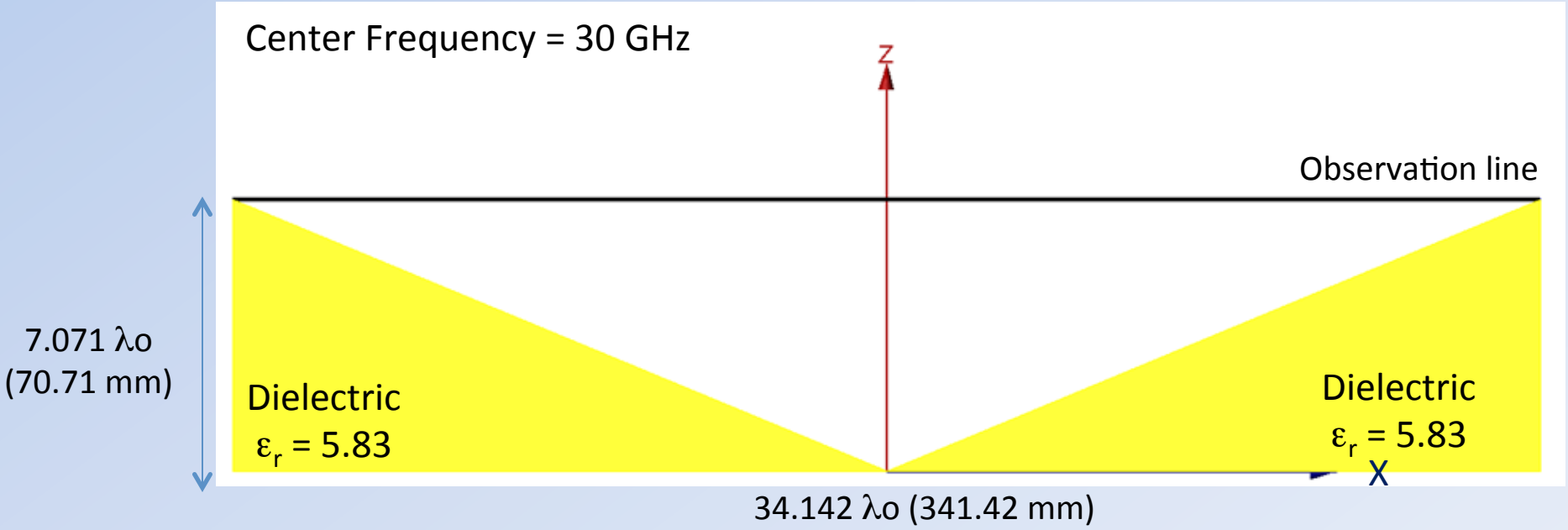


- The proposed IPA uses two right-angled triangular prisms to divert the wave that impinges upon the base of the prism at an angle away from the zenith
- Our ultimate goal is to achieve adequate suppression of the radiation along the zenith and divert the energy to oblique angles.
- A plane wave propagating along the positive z-direction, with its electric field polarized along the x-direction has been used to excite the double prism
- The structure is finite along x- and z-directions while infinite along y-direction

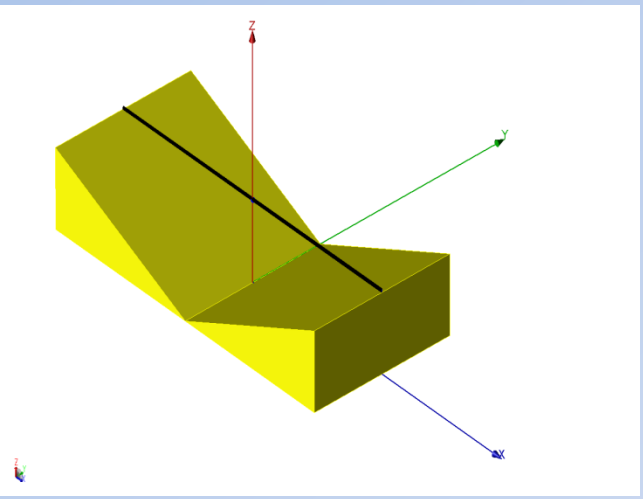
The IPA Parameters

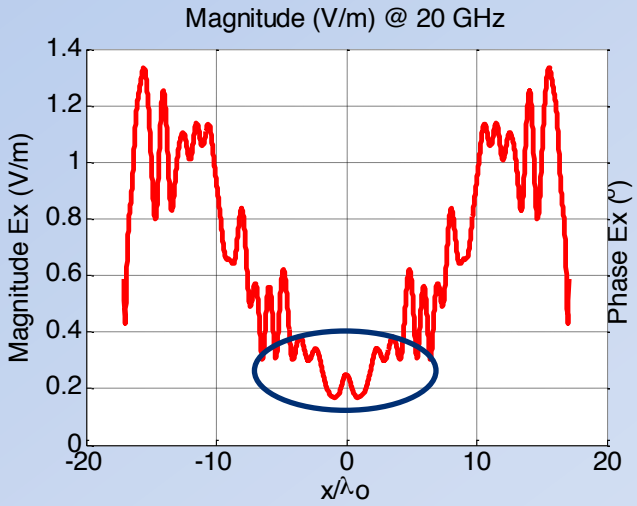


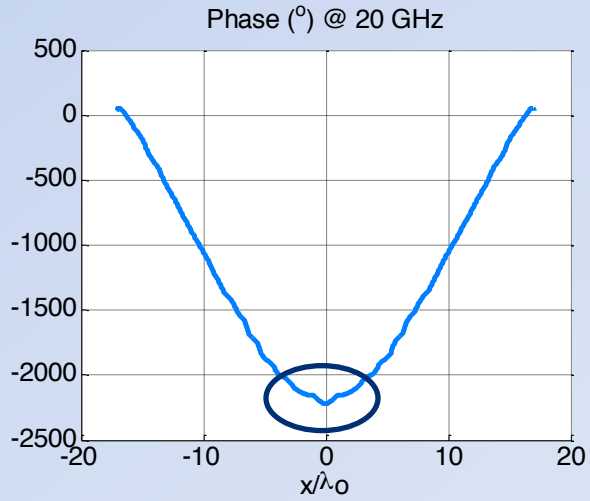
MAIN ISOFLUX PATTERN STRUCTURE

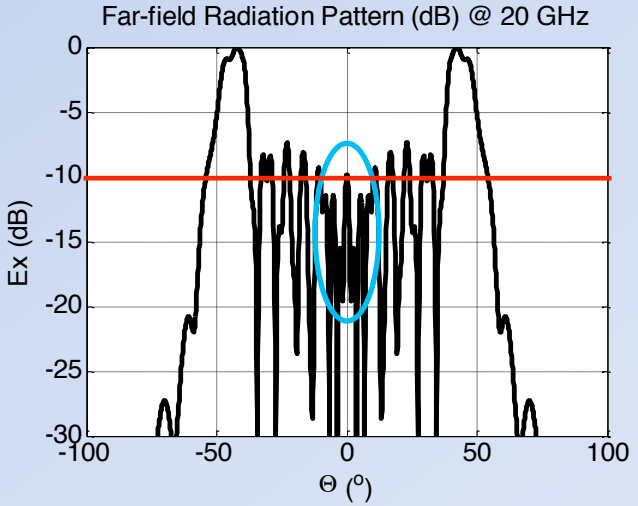


Results for the IPA @ 20 GHz



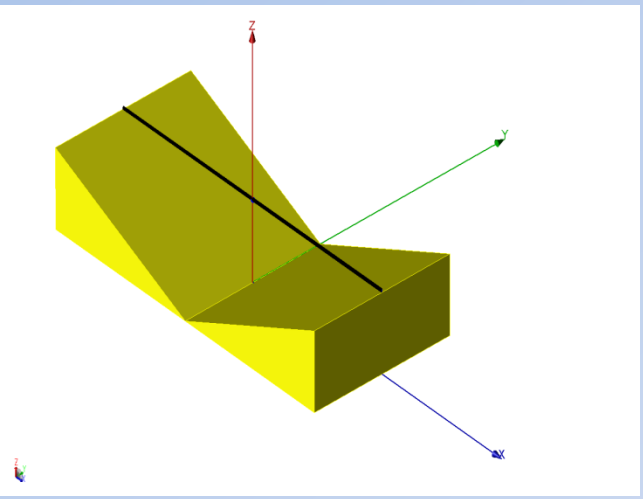


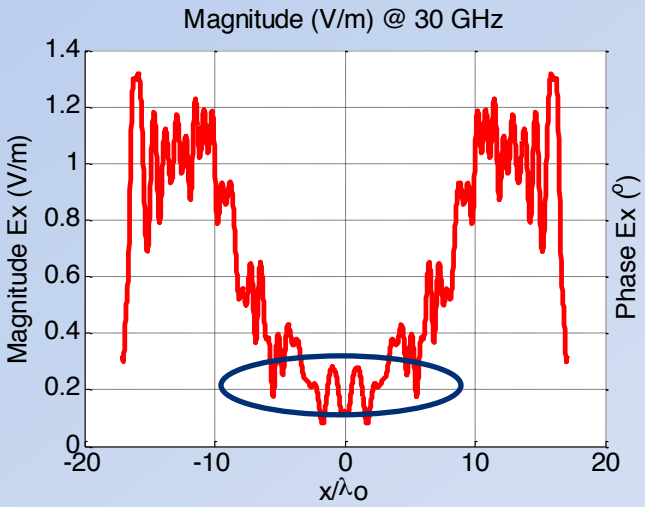


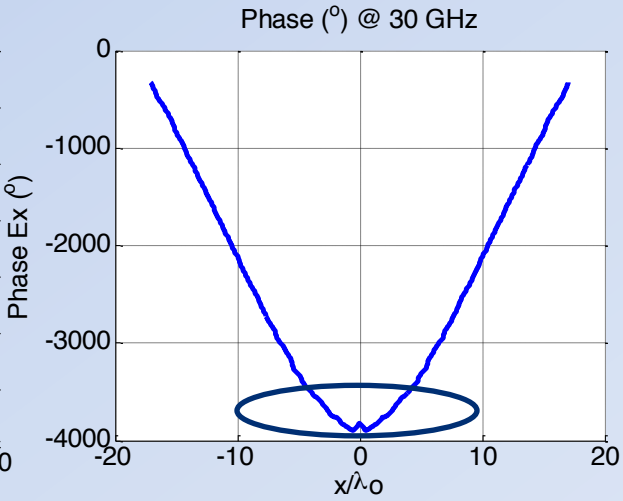


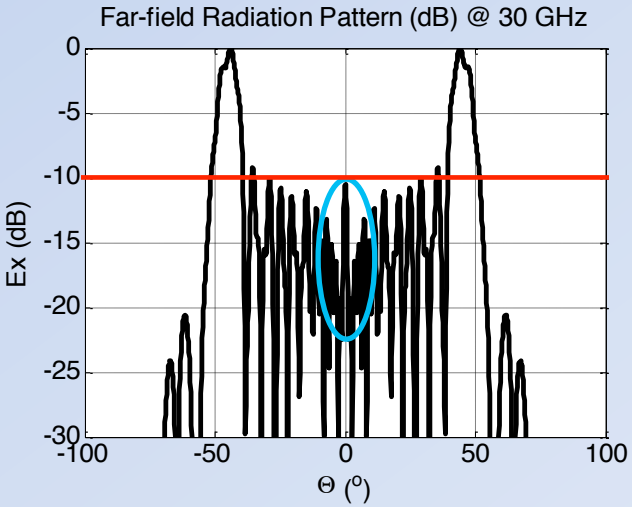
The phase taper has been nearly achieved. As a result, the main lobes are directed away from broadside in the far-field radiation pattern. However, there are some residual artifacts in the pattern along the zenith.

Results for the IPA @ 30 GHz



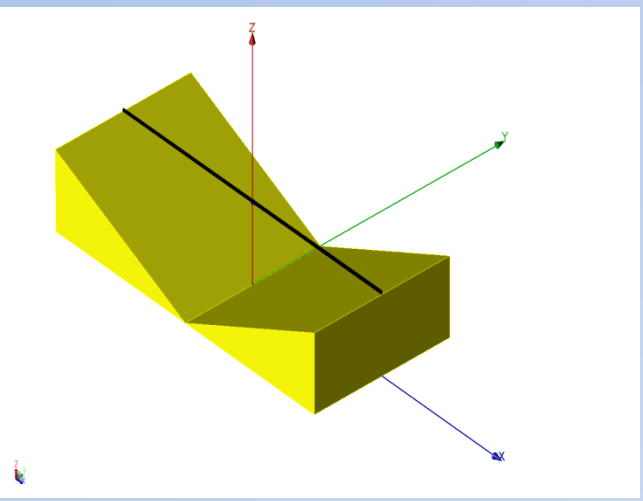


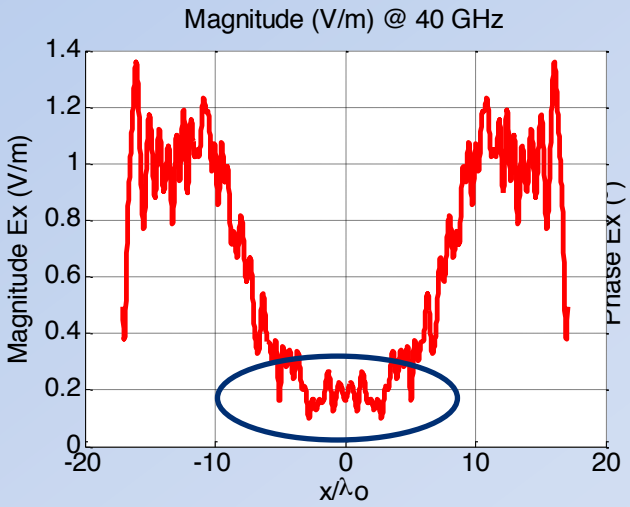


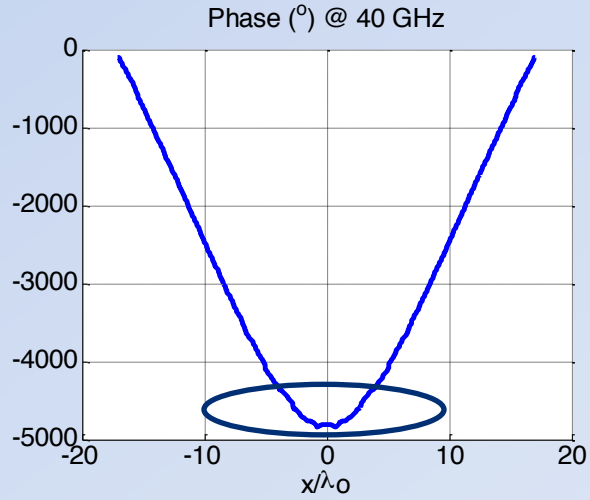


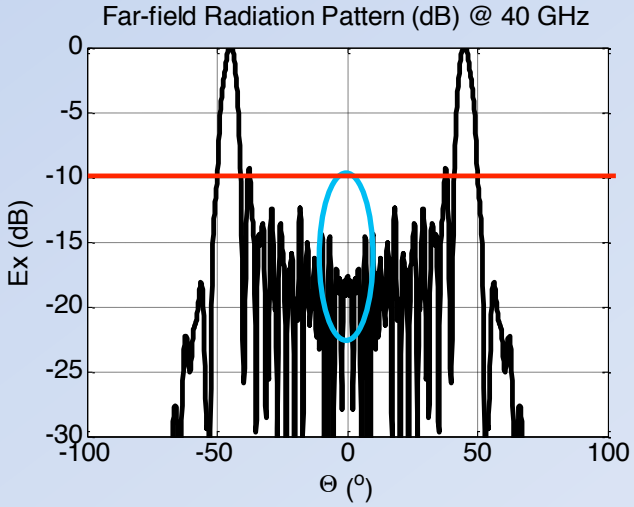
The phase taper has been very nearly achieved. As a result, the main lobes are directed away from broadside in the far-field radiation pattern. However, there are still some residual artifacts in the pattern along the zenith.

Results for the IPA @ 40 GHz



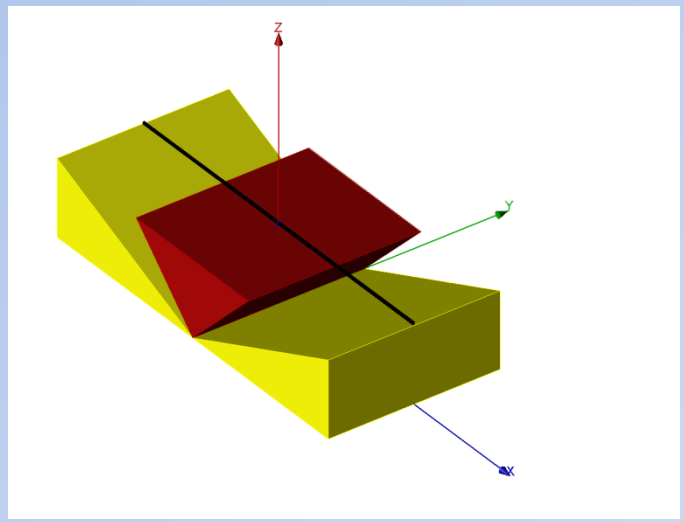


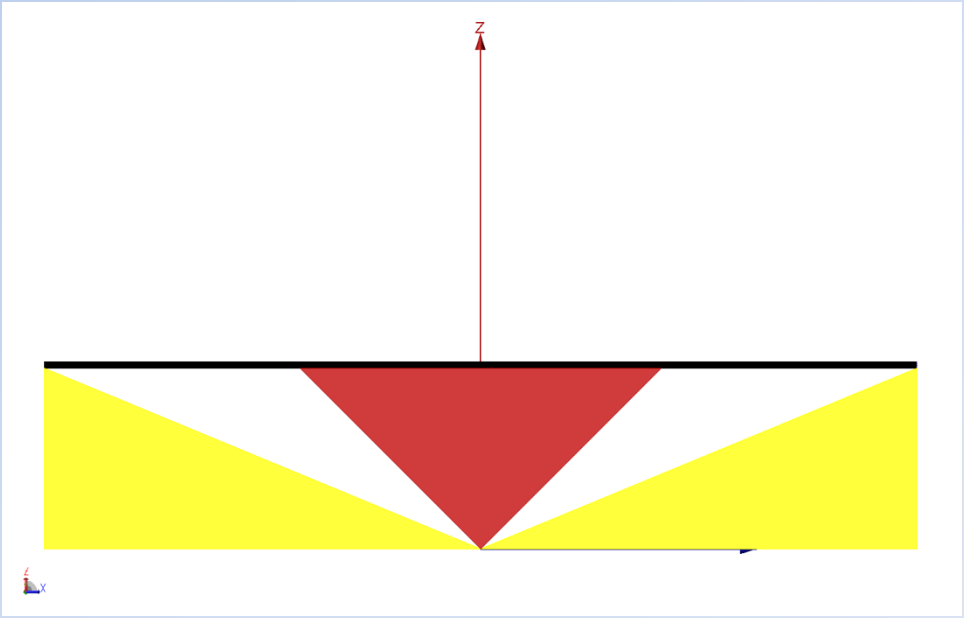




The ideal phase taper has been very nearly achieved and the magnitude distribution is also sufficiently close to desired. Hence the radiation along the zenith is adequately suppressed.

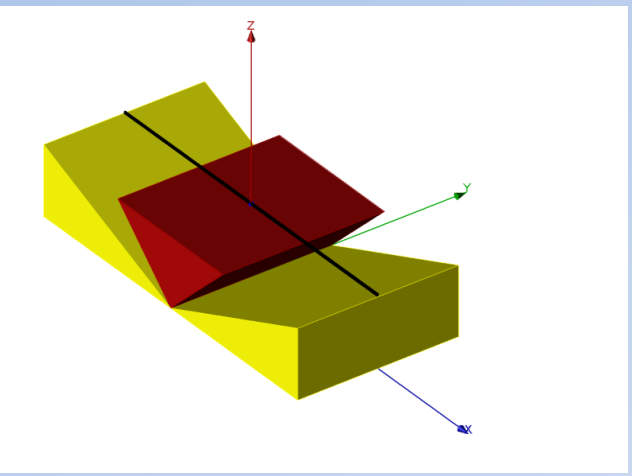
The IPA with Sharp-Edged PEC Filter

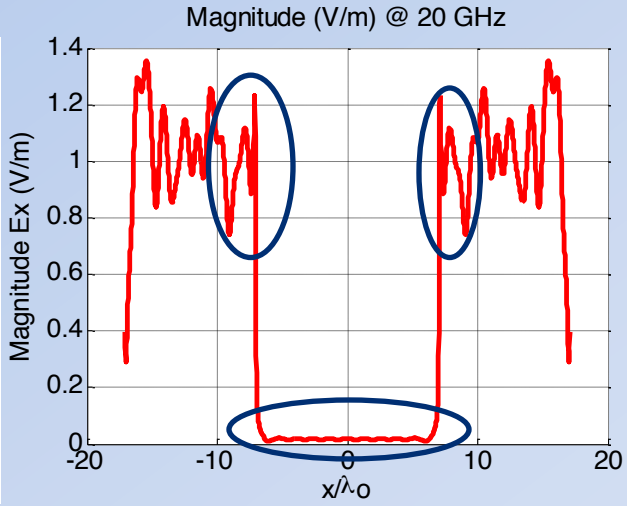


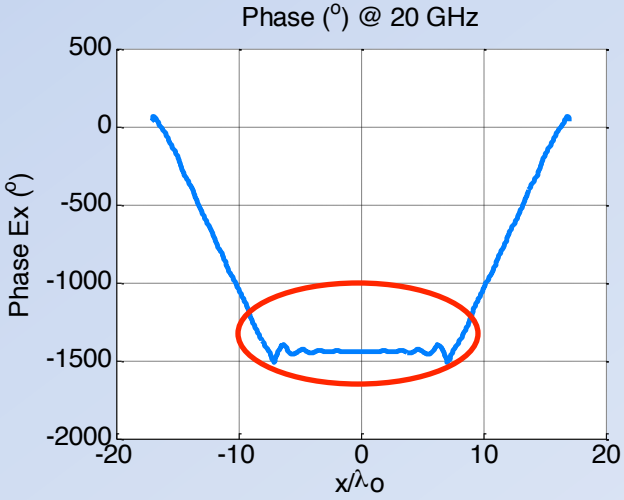


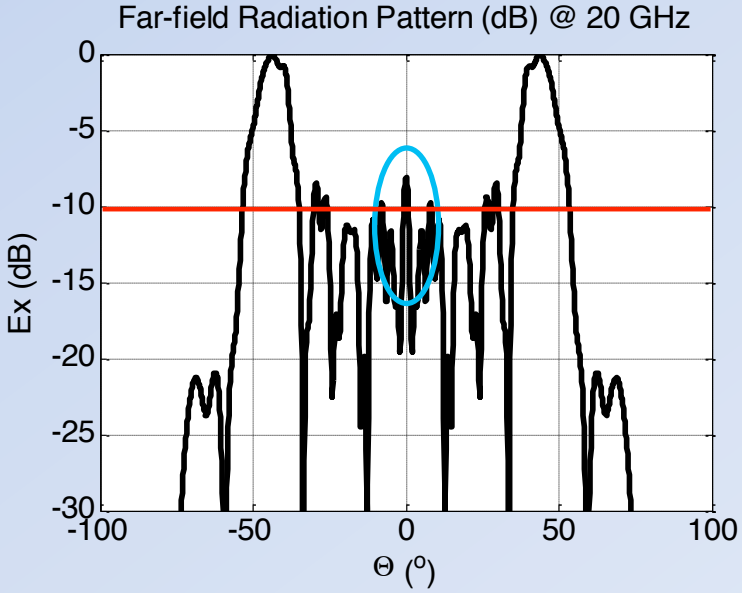
- Next, we introduce an inverted prism-shaped PEC structure to achieve further suppression of the radiation along the zenith
- The dimensions of the filter prism are: height = $7.071\lambda_0$; side length = $7.071\lambda_0$; and base = $14.142\lambda_0$
- The excitation used is the same as in the previous case, and the steps for the computation of the field distribution on an observation line just above the structure, as well as for the derivation of the far-field radiation pattern, remain unchanged

IPA W Sharp-Edged PEC Filter@ 20 GHz

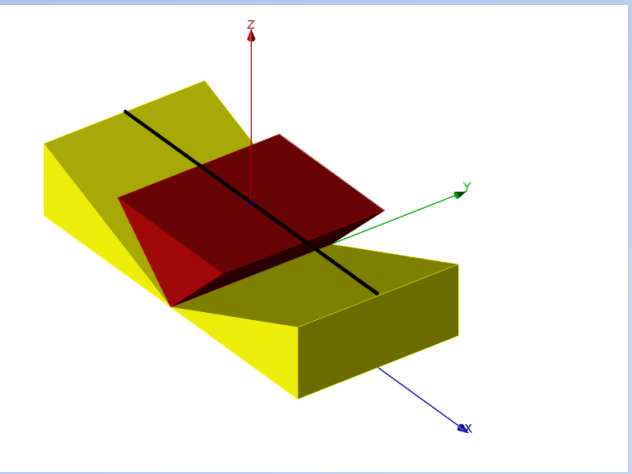


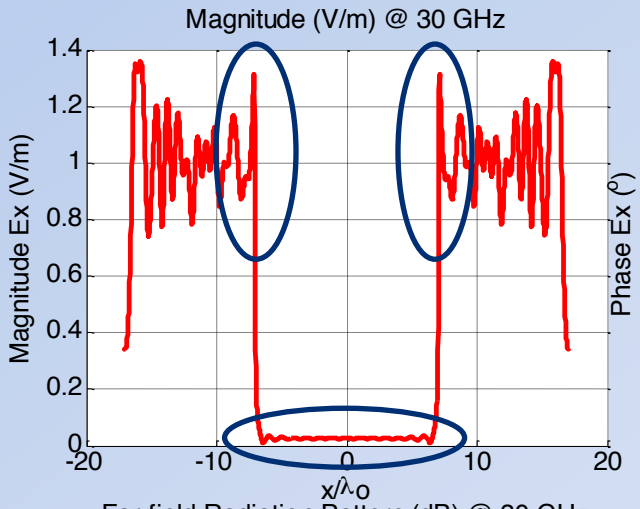


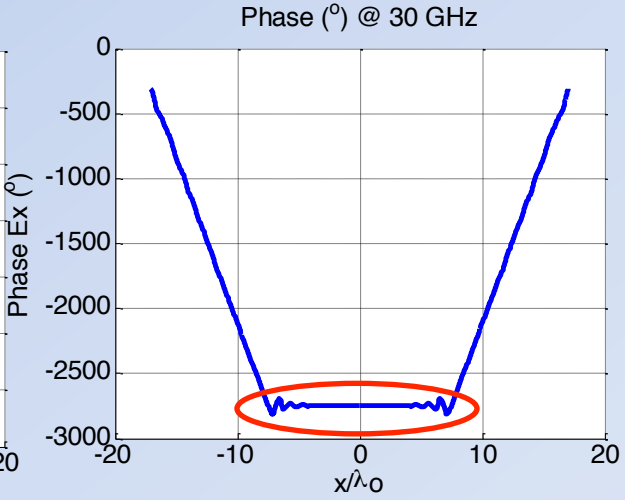


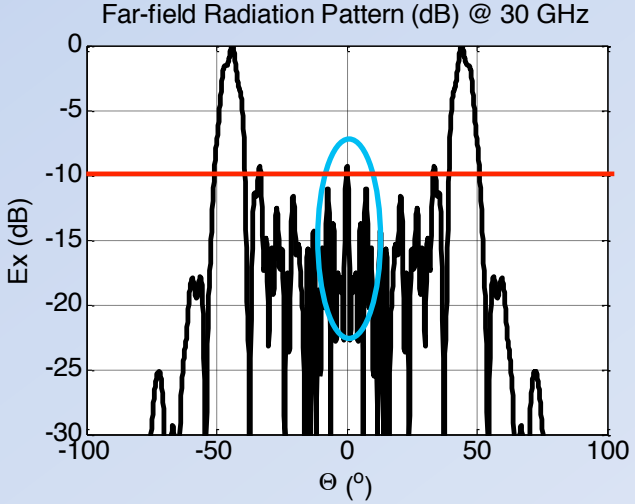


IPA W Sharp-Edged PEC Filter@ 30 GHz



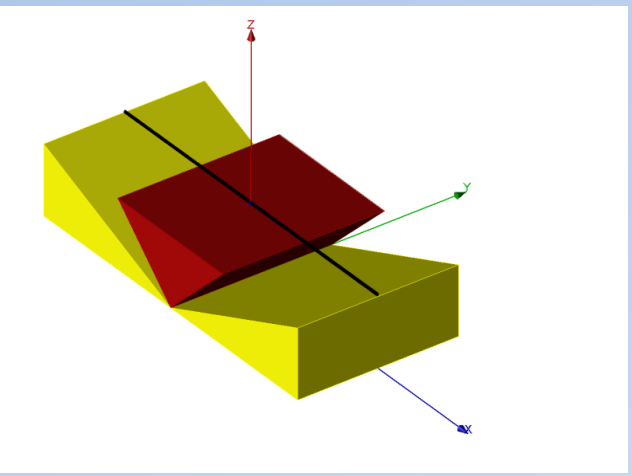


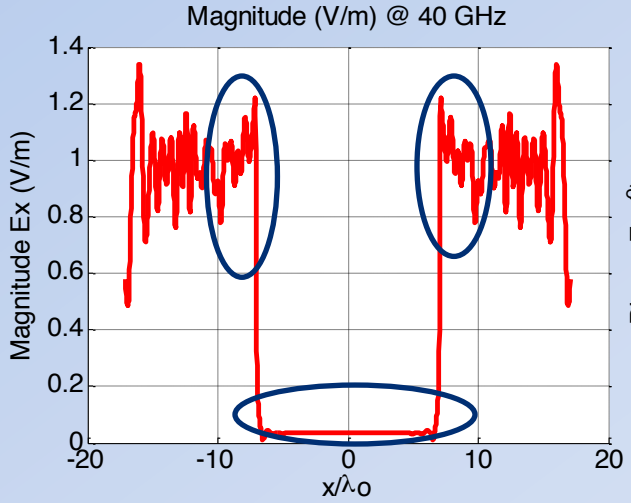


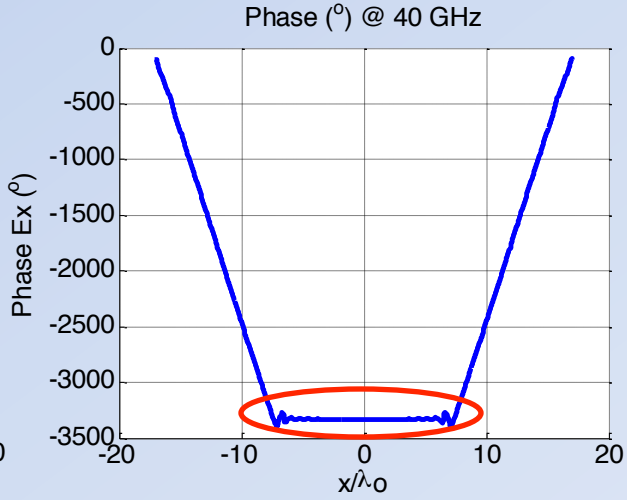


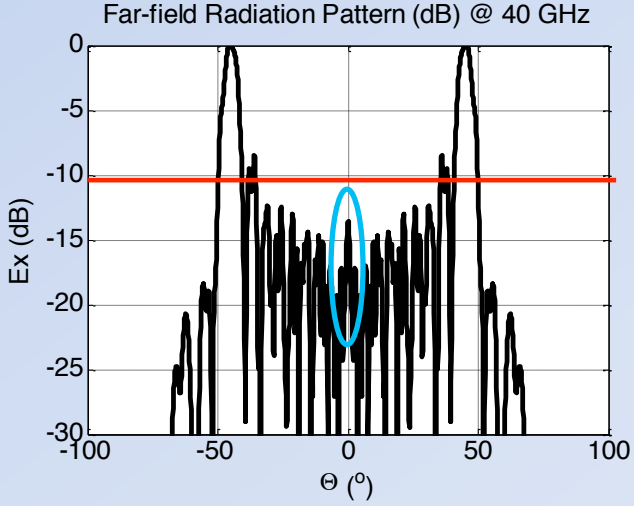
From the results obtained, it seems that the Isoflux radiation pattern had been formed at +/- $\pi/4$ while the radiation along the zenith is not completely suppressed due to residual scattering from the sharp edges

IPA W Sharp-Edged PEC Filter@ 40 GHz



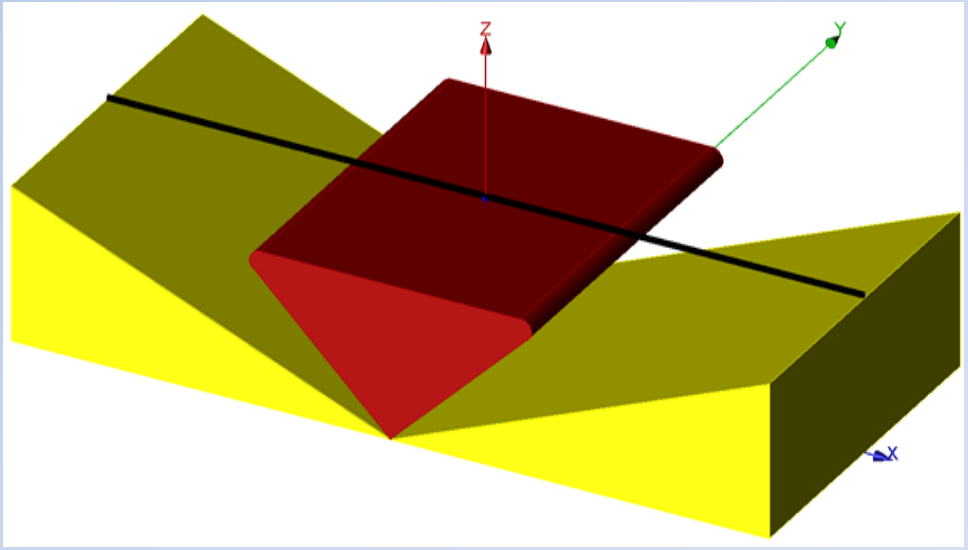






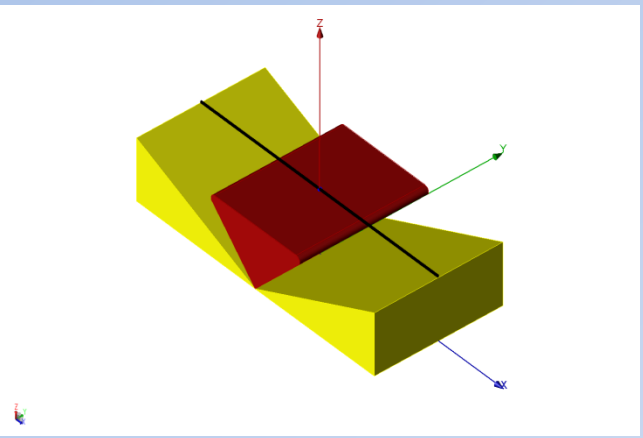
From the results obtained above, the Isoflux pattern had been formed at +/- π/4 and the normal direction radiation is significantly suppressed

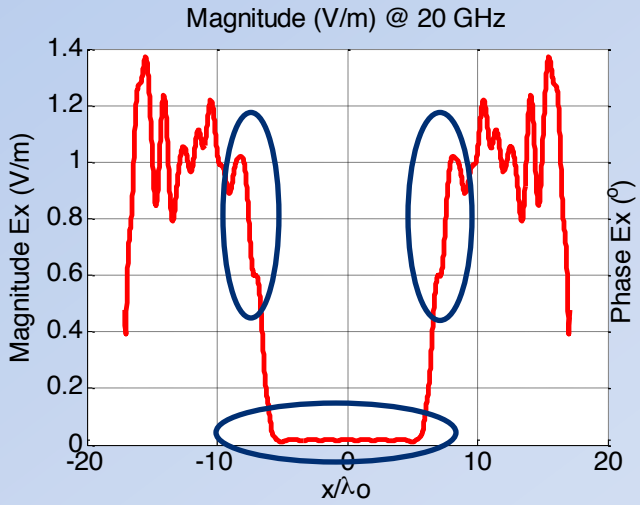
The IPA with Round-Edged PEC Filter

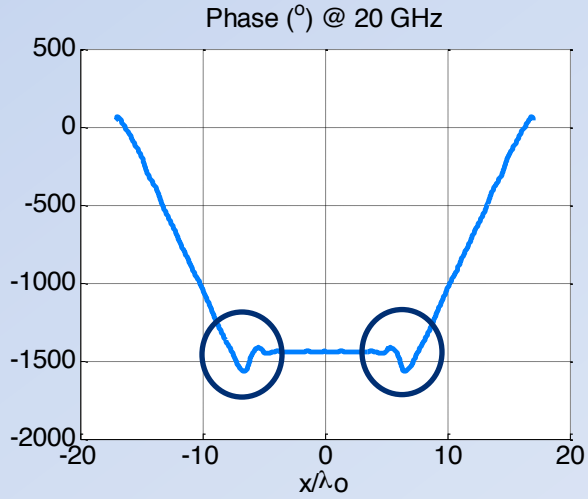


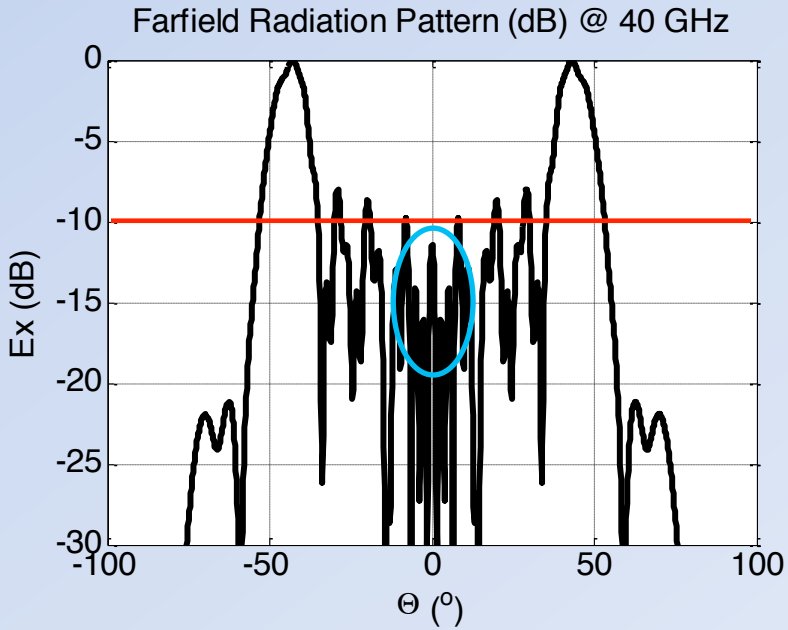
Next, the IPA structure is modified by rounding the edges of the PEC filter shown above to help suppress and eliminate residual scattering from the sharp edges

IPA W Round-Edged PEC Filter@ 20 GHz

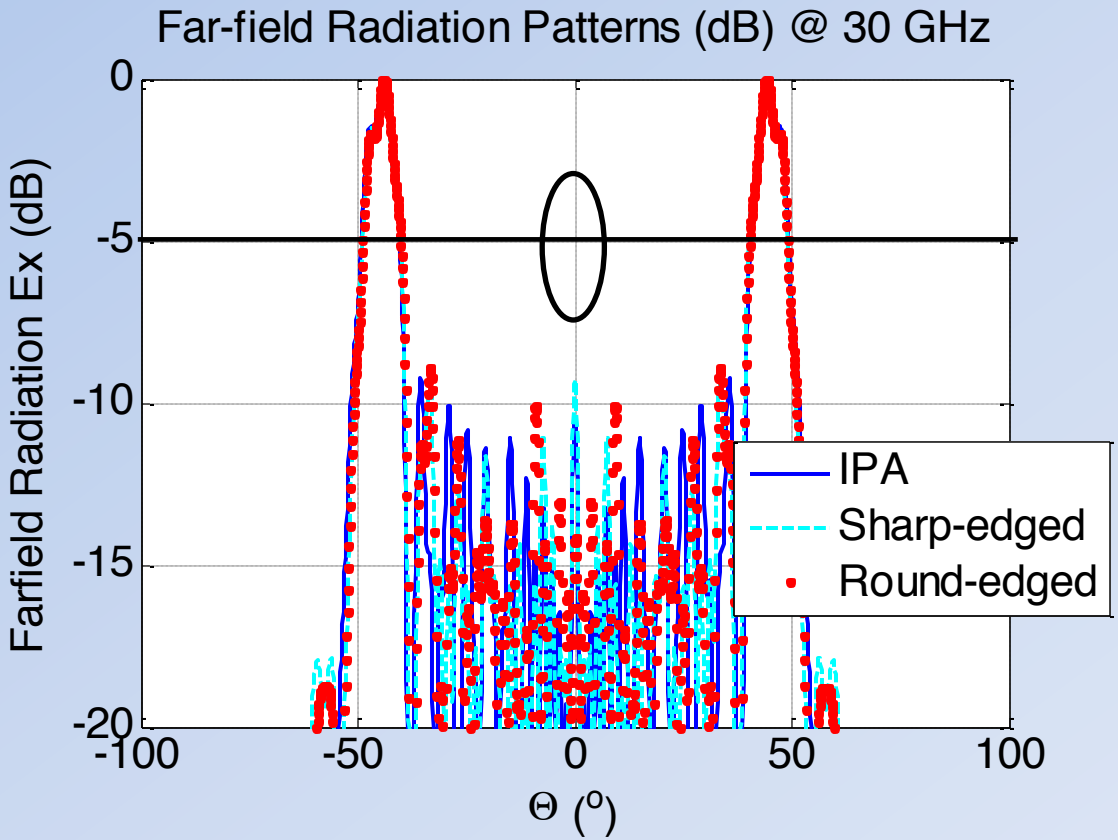


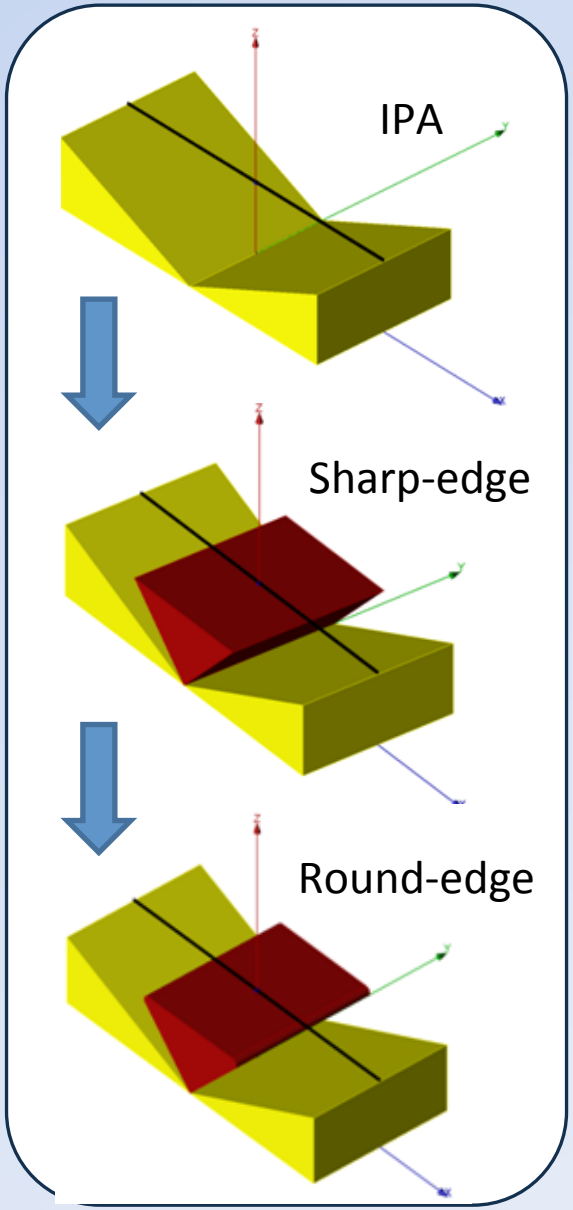




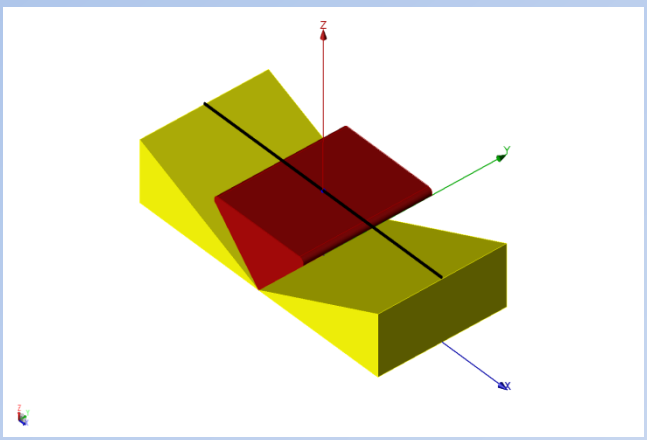


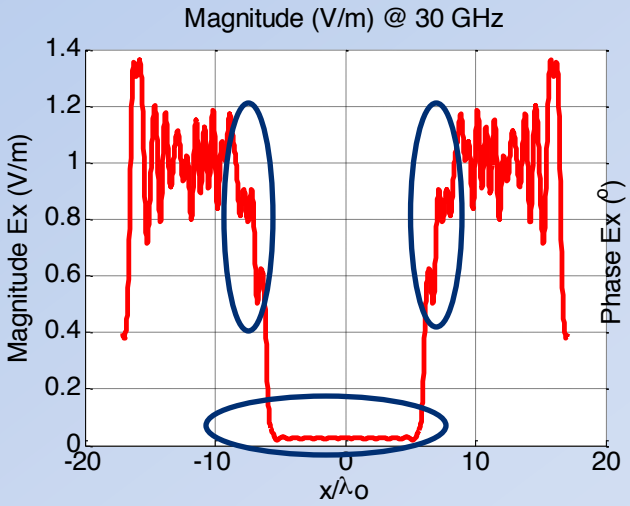
Far field Radiation Patterns Comparison

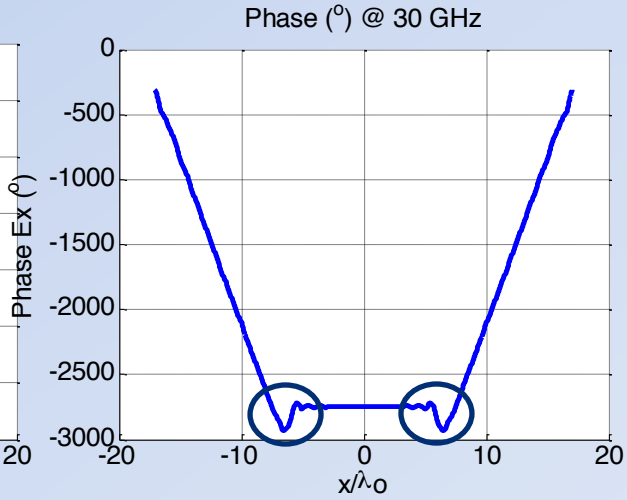


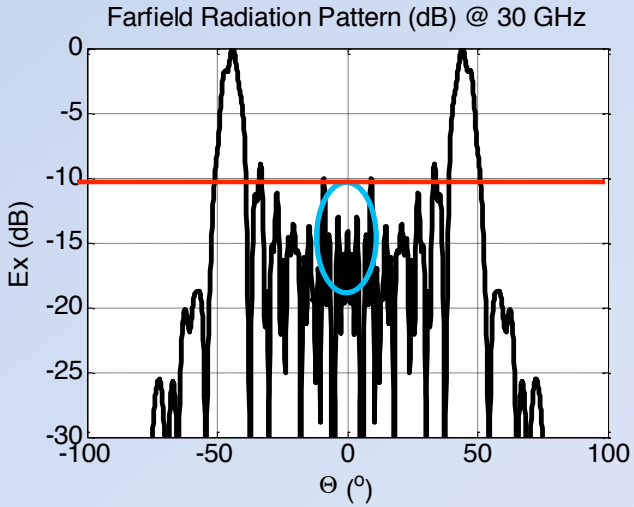


IPA W Round-Edged PEC Filter@ 30 GHz



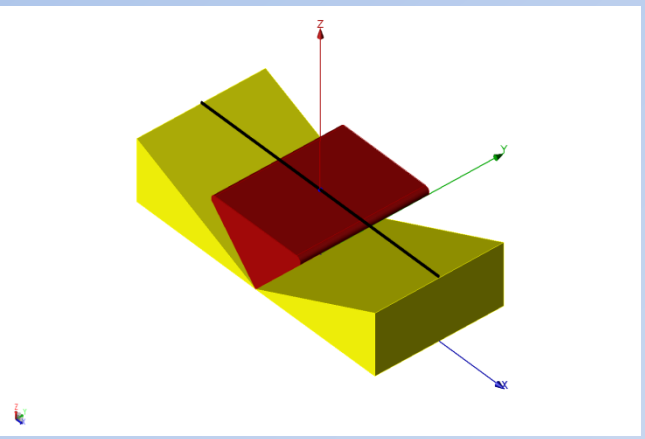


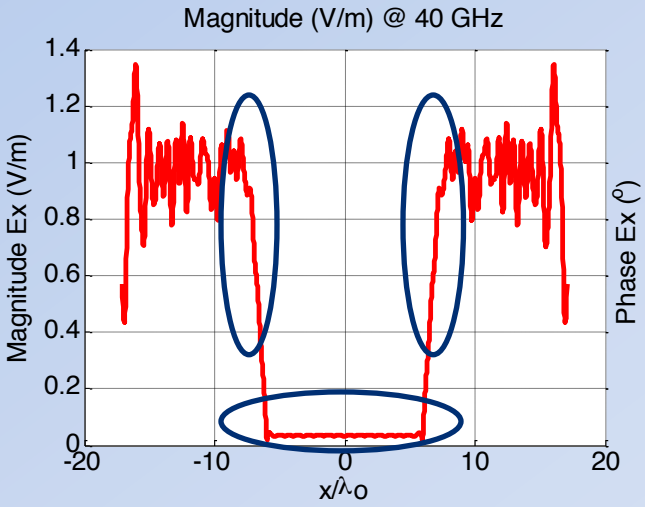


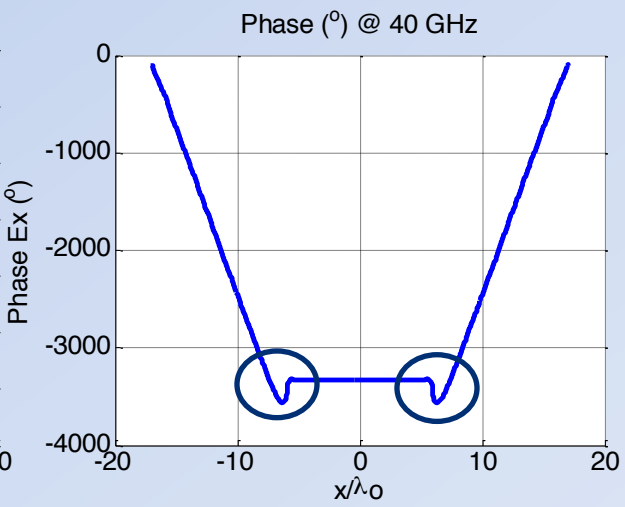


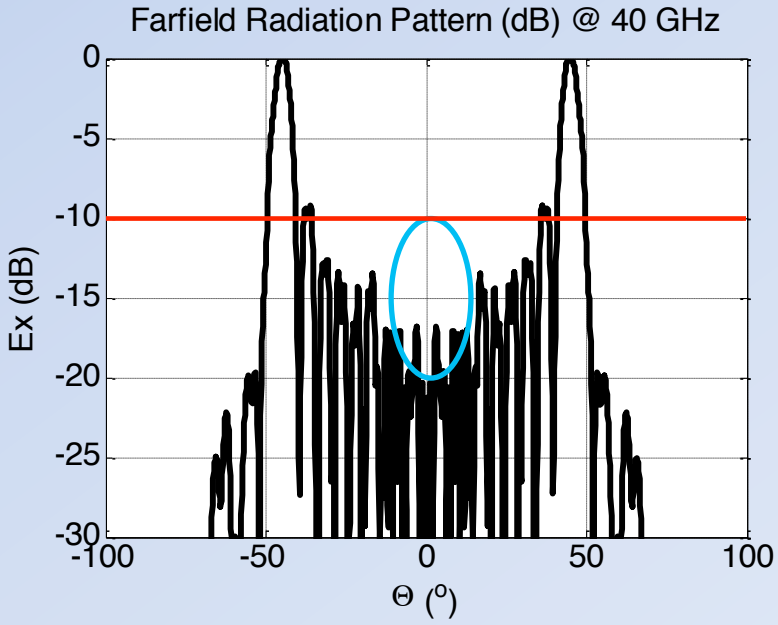
From the results obtained, it seems that the Isoflux radiation pattern had been successfully formed at +/- π/4, while the radiation along the zenith has been completely suppressed and the side-lobes had been massively reduced

IPA W Round-Edged PEC Filter@ 40 GHz

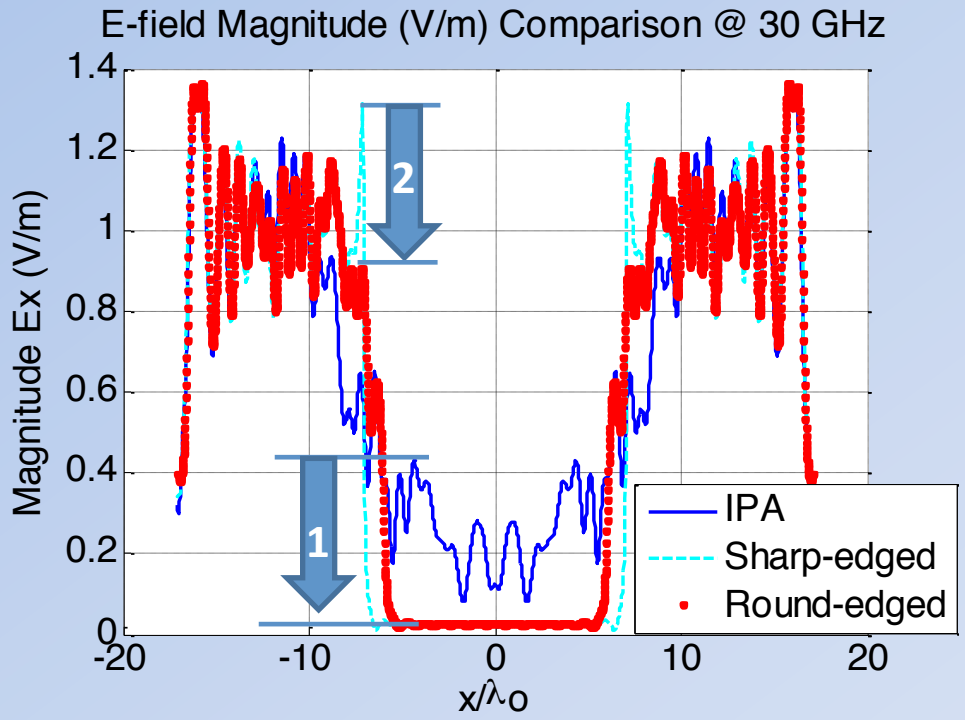


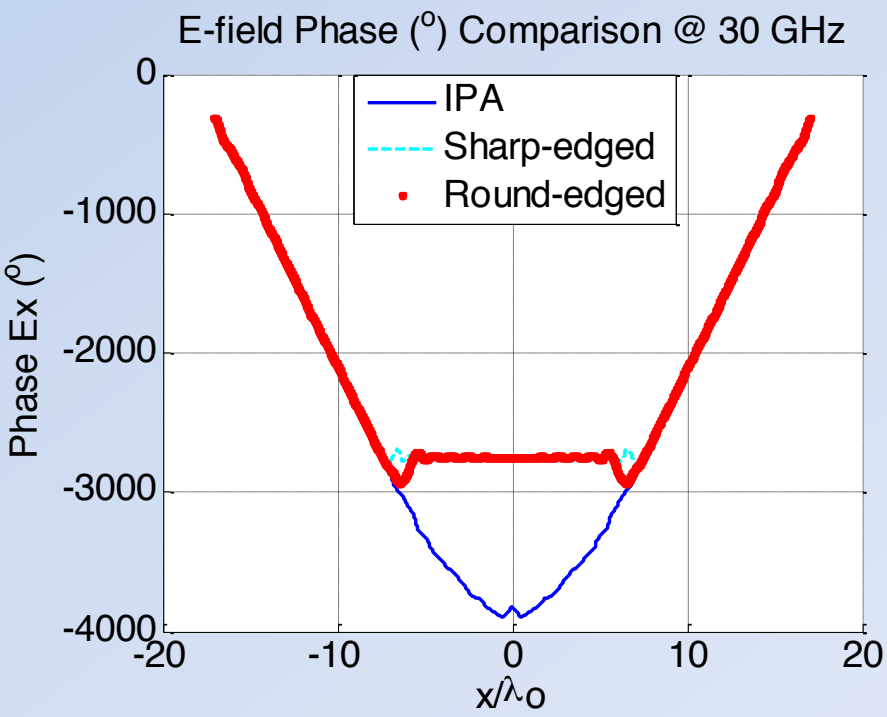






E-field Magnitude & Phase Comparisons





1) Introduction of the <u>inverted prism filter</u> helps bring the magnitude level down to the desired level

2) <u>Rounding the prism edges</u> helps eliminate some artifacts in the magnitude distribution that were causing undesired radiation along the zenith in the far-field pattern

Conclusion

- In this work, we have presented a design of an antenna that generates an Iso-flux radiation pattern, with its two main beams pointing at specified angles away from the zenith
- From the results obtained, we have demonstrated that the IPA with the Round-Edged Prism was able to completely suppress the radiation along the zenith
- These types of antennas can be used to suppress radiation along the zenith as well as direct the beams at specific angles